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ALGORITHM FOR CONTROLLING MULTI-COORDINATE MECHATRON MODULES OF AN INDUSTRIAL ROBOT

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Abstract. The paper discusses the algorithm for controlling multi-coordinate mechatron modules of an industrial robot, which is widely used in manufacturing. At the same time, the working principles of industrial robots and their control algorithms are analyzed based on mathematical models that have a clear solution. Algorithms based on mathematical models, on the other hand, involve the movement of robots in precise coordinates. An important aspect of the research is the algorithm for controlling the multi-coordinate mechatron modules of an industrial robot, which allows to obtain interactions with a manipulating object and movements on several linear and angular coordinates in a single output, which reduces the weight and size of the robot and improves its dynamic properties. The multi-coordinate mechatron modules of an industrial robot with such control also increase the quality of production.

Keywords: Multi-coordinate module, industrial robot, mechatronic module, algorithm, manipulative object.
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1 Introduction

Automation of production processes in modern manufacturing enterprises is associated with the correct organization of the management of industrial robots. The use of robots and robotic systems in industry reduces the processes involving the human factor, albeit slightly, as well as weight, used in places dangerous to humans (fire, mining, underwater, underground. The accuracy of the location and dynamics of the robotic manipulator is largely determined by the properties of the object-based mathematical model and control algorithms (Angeles & Angeles, 2002; Gancet et al., 2005). The impact of the robots on the object depends on its working body (WB), handle, and some sensor devices that are in direct contact with the external environment.

2 Literature review

The development of multi-coordinate mechatron modules of industrial robots, their mathematical models and control algorithms is a topical issue for researchers conducting research in this field. The principles of robotics have been reflected in the research of many scientists around the world. In this regard we would like to note the works by Ignatiev, Yu. Poduraev, V. Egorov, A.A. Kobzev, Yu.E. Mishulin V. Nemontov, E.P. Popov, V.V. Klyuevas E.V. Vorobiev, A.B. Babich, M. Shakhinpur. In these works the importance of the underlie the creation of a mechatronic module and a mathematical model of mechatronic modules were underlined. In particular, very important research is being carried out in Uzbekistan at Tashkent State Technical University, Turin Polytechnic University, and Fergana Polytechnic Institute. It should be noted also rgw scientists such as N.R. Yusupbekov, P.F. Khasanov, A.A. Khalikov, B.M. Azimov, I.Kh. Siddikov, M.M. Kamilov, M.F. Zaripov H.N. Nazarov, M.M. Abdullaev, S.F. Amirovs who make a huge contribution on the topic.

3 An industrial robot and manipulation object based on a multi-coordinate mechatron module

The increasing demand for intelligent systems of automatic control requires the control and use of robots with an intelligent single-coordinate mechatron module. Because they reduce functionality, weight and size, improve dynamic properties. Figure 1 below shows a robot based on a multi-coordinate mechatron module and the appearance of its manipulative object.

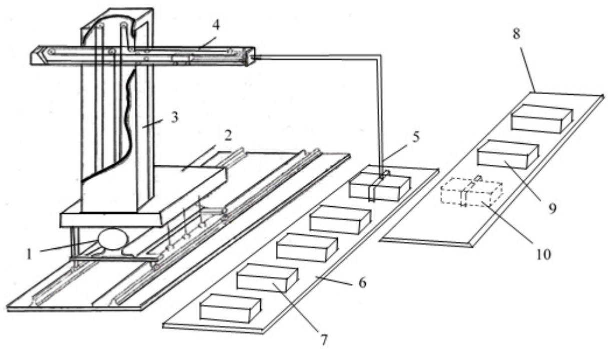

Figure 1: An industrial robot based on a multi-coordinate mechatron module
1 - multi-coordinate mechatron module, 2 - horizontal movement link on the y axis, 3 - vertical movement link on the z axis, 4 - horizontal movement link on the x axis, 5 - clamping device, 6-cone, 7 -detail, 8-manipulative object, 9-detail transferred to the manipulated object, 10- location (sketch) of the detail transferred to the manipulative object.

An industrial robot operating in the Cartesian coordinate system consists of multi-coordinate mechatron module (1), where u is a moving link (2), z ia a vertically moving link (3), x is a horizontal moving module (4), clamping device (5), condenser (6), detail (7), detail (9) transferred from the manipulating object (8) to the manipulating object, and detail sketch (10).

4 Analysis and results

The main features of this robot are that the overall dimensions and mass indicators are small, the dynamic characteristics are improved, and a single multi-coordinate mechatron module allows you to get all the movements. The development of such industrial robots from the path of perfection increasing the level of versatility will inevitably lead to the complexity of control systems. To achieve these capabilities, mathematical models and algorithms with certain calculations are needed (Angeles & Angeles, 2002; Ignatiev et al., 1972; Medvedev et al., 1978). Based on mathematical models and algorithms, software that controls the movements of robots is created with the help of certain programming languages. Mathematical models and algorithms based on them calculate the general coordinates of the manipulator and their changes in the process of performing the actions specified by the robot. As an example, we can take the task of several operations that control the movement of the manipulator:

1) determine the coordinates of the geometric center of the detail and its direction in space;
2) calculation and verification of the trajectory of the handle to the detail;

3) recalculation and verification of the trajectory of motion from the Cartesian coordinates to the generalized coordinate system of the robot;

4) go the calculated trajectory;

5) check and determine the movement of the detail; 6) check and control the trajectory of the handle movement with the part to the assembly area;

7) check that the calculation of the return of the robot to the final trajectory generalized to the general coordinate system is performed;

To obtain a detail whose coordinates and direction are determined, the robot is brought to the center corresponding to the center of the handle and moved accordingly. The algorithm for controlling industrial robots to perform the above actions is shown in Figure 2.

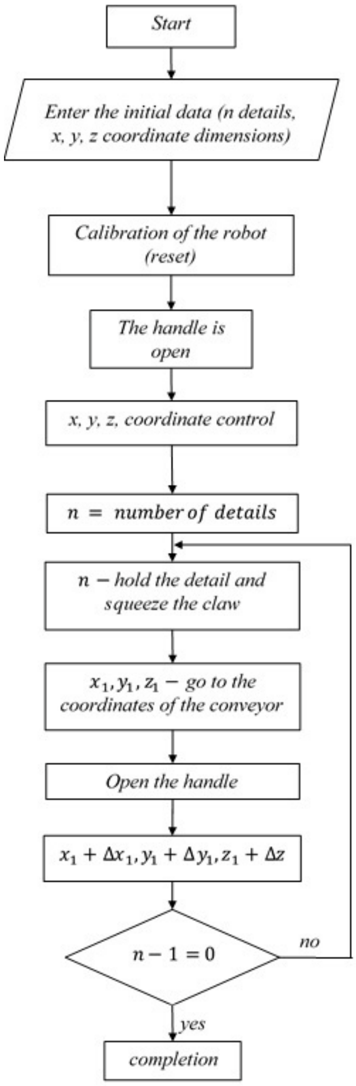

Figure 2: Algorithm for controlling industrial robots

It can be seen from the algorithm that robots can be controlled with a multi-coordinate mechatron module in terms of accuracy and speed, (Nazarov, 2006; Nazarov, 2019) the following mathematical calculations are performed as the value of the algorithm, as described in the literature.

Step 1. By calculating the robot's positioning accuracy and service time, the handle coordinates can be taken as initial information.

$$x_{cx} = R\cos\varphi_1 = \sqrt{h^2 + S_3^2}\cos\varphi_1;$$
$$y_{cx} = R\sin\varphi_1 = \sqrt{h^2 + S_3^2}\sin\varphi_1; \tag{1}$$
$$z_{cx} = S_2$$

Step 2. To calibrate the robot (reset), to check for errors, you can write the following expression in the number of generalized coordinates:

$$\Delta x = \sqrt{h^2 + S_3^2}\sin\varphi_1\Delta\varphi_1 + \cos\varphi_1\frac{S_3}{\sqrt{h^2+S_3^2}}\Delta S_3;$$
$$\Delta y = \sqrt{h^2 + S_3^2}\cos\varphi_1\Delta\varphi_1 + \sin\varphi_1\frac{S_3}{\sqrt{h^2+S_3^2}}\Delta S_3; \tag{2}$$
$$\Delta z = \Delta S_2$$

In industrial robots, when the coordinates of the rising point have dimensions $x_{cx} = 0,\ y_{cx} = 1,8\ z_{cx} = 1,7m$, we write the following system of equations when the position of the robot handle corresponds to the position of the robot.

$$\begin{cases} \sqrt{h^2 + S_3^2}\cos\varphi_1 = 0 \qquad h = 0,5; \\ \sqrt{h^2 + S_3^2}\sin\varphi_1 = 1,8; \\ S_2 = 1,7. \end{cases}$$

Step 3. Whether the robot handle is open or closed is checked in time, just like the initial calibration process (Figure 3), and on this basis the robot moves along the x coordinate when lifting the part.

When raising the detail to $a = 90°$, it is taken into account that in this case the maximum door angle of the mechatron module is $\varphi = 30°$. Based on the above expression, it is possible to detect errors in the calculation of the determined values of the generalized coordinates and to determine the errors of the robot handle on each axis using the technical characteristics of the mechatron module by the following expressions:

$$\Delta x = -\sqrt{h^2 + S_3^2}\sin\varphi_1 + cos\varphi_1\frac{S_3}{\sqrt{h^2+S_3^2}}\Delta S$$
$$\Delta y = \sqrt{h^2 + S_3^2}\ \cos\varphi_1 \bullet \Delta\varphi_1 + sin\varphi_1\frac{S_3}{\sqrt{h^2+S_3^2}}\Delta S_3$$
$$\Delta z = \Delta S_2$$

Based on the above, it is possible to determine the maximum error of the coordinates:

$$\Delta\rho_1 = \sqrt{\Delta x^2 + \Delta y^2 + \Delta z^2}$$

Step 4. When a certain time is set, the robot rotates along the $y-$axis $\varphi_1 = 90°$. Here again it is necessary to take into account that for the maximum 30° turn means that the whole operation is carried out in three stages (Nazarov *et al.,* 2020; Popov, 1995; Sung, 2019). If the robot does not reach the specified coordinates, then the robot's motion is calibrated again in watts according to the following algorithm (Figure 3).

On this basis, the position of the robot in the manipulated object is also checked over time (Figure 4). This algorithm checks the position of the handle after receiving the detail, ie the position of the handle.

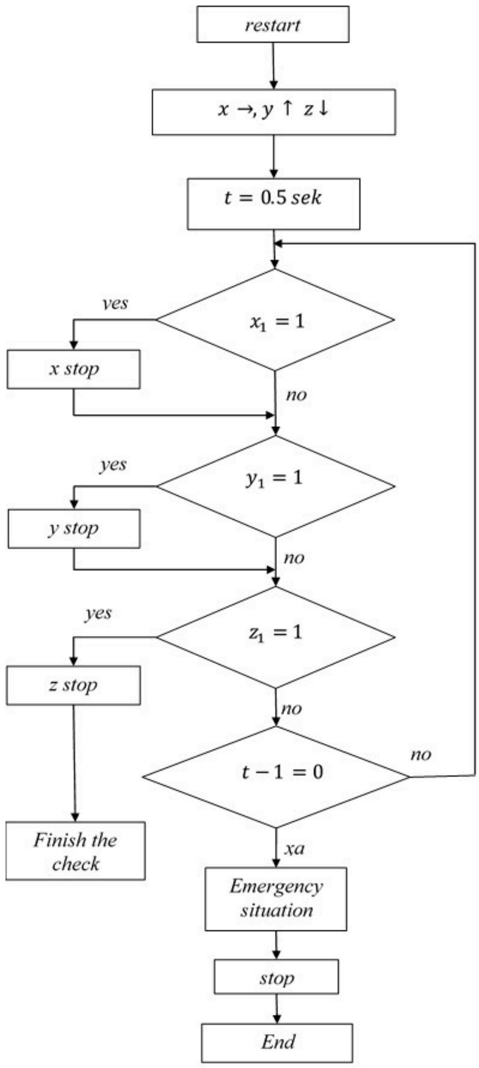

Figure 3: Algorithm for calibrating robot coordinate motion

In the study of the state of the handle, the algorithm is mainly characterized by the following conditions:

$a-$handle;

1 handle position;

$b-$ Detailed position of the handle 1,

failure status is rated at 0;

$T-$set time;

$n-$cycle.

Step 5. The robot manipulator is twisted and the handle release command is executed. If the handle is not opened (Fig. 3), as mentioned above, the handle has a sensing sensor, which indicates the position of the handle in the "unopened" position, ie the $b-$ handle is checked by the leak sensor.

When the handle is open, the next step begins and the cycle continues (Yusupbekov et al., 2015; Nodirbekovich *et al.,* 2020; Zenkevich, 2004).

Step 6. The rotation of the robot along the $y-$ axis $\varphi = 270°$ rotates the robot towards the conveyor. In turn, the module performs step 9. If the robot handle does not reach the final position, the position sensor along the $y-$ axis is activated and indicates that the handle should reach the final position.

Step 7. Classification of motion along the $x-$ axis of the robot.

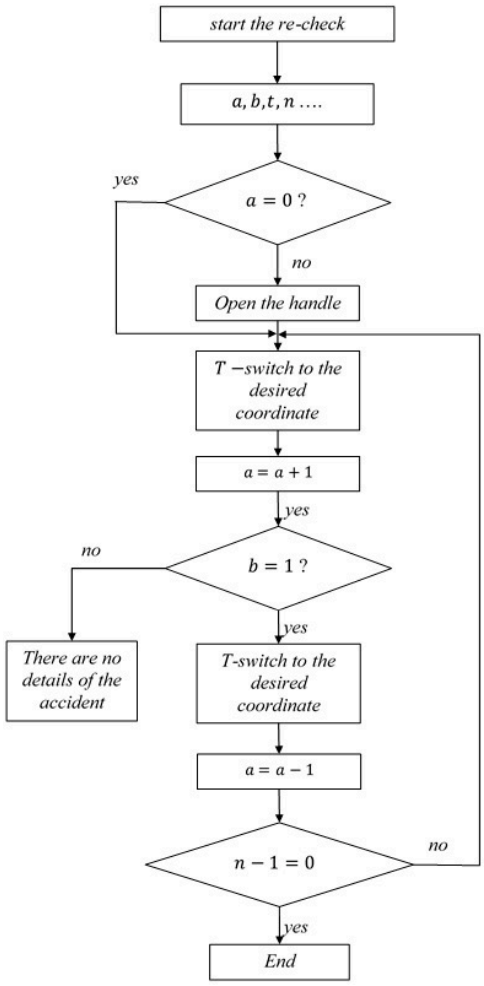

Figure 4: Algorithm for checking the position of the robot handle at the specified coordinates

The robot manipulator moves along the $x-$ axis $a = -90$ °. In the manipulated object, the robot arm is rotated towards the conveyor at $a = 90°$ and reset by initial calibration. If the manipulator does not reach the final state, the operation is restarted. In that case, the robot starts its movement from the beginning and automatically stops the movement of the robot when the details are finished.

5 Conclusion

The structure of the algorithms in the precise control of the robot's motion reflects the principle of operation of robots based on the electromagnetic mechatron module. Analyzing the computational results obtained, we can conclude that the coordinates of the initial position of the robot are slightly different. The proposed algorithm leads to a comparison of technical and economic parameters and an increase in the ease of maintenance of robots.

References

Angeles, J., & Angeles, J. (2002). *Fundamentals of Robotic Mechanical Systems* (Vol. 2). New York: Springer-Verlag, 545.

Gancet, J., Hattenberger, G., Alami, R., & Lacroix, S. (2005, August). Task planning and control for a multi-UAV system: architecture and algorithms. In *2005 IEEE/RSJ International Conference on Intelligent Robots and Systems* (pp. 1017-1022). IEEE.

Ignatiev, M.V., Kulakov, F.M., & Pokrovsky, A.M. (1972). Algorithm for controlling robotic manipulators. *Mechanical Engineering*, 248 (in Russian).

Medvedev, V.S., Leskov, A.G., & Yushchenko, A.S. (1978). *Control Systems for Manipulation Robots*. Moscow: Nauka, 416 (in Russian).

Nazarov, Kh.N. (2006). On the concept of constructing multi-axis mexatronic modules for the movement of intelligent robots. *Chemical Technology, Control of Management,* 5, 5-7 (in Russian).

Nazarov, Kh.N. (2019). Intelligent multi-axis mexatronic modules of robotic systems. *Mashhur-Press*, 143 (in Russian).

Nazarov, K.N., Matyokubov, N.R., & Rakhimov, T.O. (2020, October). Simulation Model of the Multi-position Mechatronic Module Functioning of an Intelligent Robot. In *World Conference Intelligent System for Industrial Automation* (pp. 201-206). Springer, Cham.

Nodirbekovich, Y.A., Nuritdinovich, N.K., Rustamovich, M.N., & Rakhimov, T.O. (2020). Conceptual basis for modeling multi-cordinate mechatronic robot modules. *Chemical Technology, Control and Management*, *2020*(4), 10-15.

Popov, E.P. (1995). Control and software of complex robotengineering systems. *Izvestiya RAN, Theory and control systems*, 1, 193-204.

Sung, Y. (2019). Multi-robot coordination for hazardous environmental monitoring. Ph.D. dissertation, Virginia Tech.

Yusupbekov, N.R., Yusupbekov, A.N. et al. (2015). *Intelligent Control Systems and Decision Making*. Tashkent: Publishing House of the National Encyclopedia of Uzbekistan, 572.

Zenkevich, S.L. (2004). *Fundamentals of Manipulation Robots Control*. Moscow, Publishing House of the Bauman Moscow State Technical University, 480 (in Russian).